REDUCING THE MANUFACTURING AND MANAGEMENT COSTS OF TRACTORS AND AGRICULTURAL EQUIPMENT

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Background

• Historically we know:
  – Agricultural equipment improves productivity and reduces drudgery.

The products and systems:
  – Must be affordable to the users
  – Profitable for the manufacturers
### Product Planning
- **Design**
- **Layout**

### Project Management & Control
- **Design**
- **In Detail**
- **Corrections, Documentation**

### Advanced Engineering
- Concepts, research, patents
- Comparisons, mock-up 1:1

### Series Maintenance
- Component Testing
- Prototype Build & Test Program
- Homologations

### Series Production
- Factory Planning
- Factory Modifying
- Or Rebuilding
- Pilot Series

### Product Development Time
(2-6 years)
Manufacturing Stressors

• Decreased sales of some product lines
• Redistribution of agriculture worldwide
• Impact of technology on the industry
  – Electronics
  – Biotechnology
• Changes and Trends
  – Manufacturing Processes
  – Design
Manufacturing Processes

Challenges for Ag Equipment Manufacturing in Completely Tractorized Countries

- Declining Unit Production Numbers
- Greater Variety of Sizes and Designs
- Shorter Lead Times
- Increased Electronics

But These Challenges Also Apply to Other Industries

- Construction Equipment
- Aerospace
Manufacturing Processes

Represent Significant Portions of Costs

• Recent Advances Can Reduce Costs

• Also Allow New Designs and Materials
  (For Example, Monolithic Parts)
Permanent Molds and Dies

Traditional: Machine Soft Steel, Heat Treat, Grind
Modern: Electrical Discharge Machining (EDM)
Now: Machine Hard Steels

Possible Due To:
- Cutting Tool Materials (e.g., CBN and Carbides)
- Understanding Structural Dynamics (Chatter Theory)
Rapid Prototyping -- Additive Processes

- Design Studies and Prototypes
- Tooling
- Limited Potential in Series Production
Lead Time: An Average Comparison

**Rapid Injection Molding**
- Part Design
- Obtain Quotation
- Mold Design
- Mold Making
- Part Molding

1 Day
1-3 Days
2-10 Days
1 Day → 5 – 15 Days

**Conventional Injection Molding**
- Part Design
- Obtain Quotation
- Mold Design
- Mold Making
- Part Molding

0-1 Week
1-3 Weeks
2-6 Weeks
1-2 Weeks → 4 – 12 Weeks

Manual
"At John Deere, we gain a major benefit using Protomold's service because they make real parts with injection molded material properties. This allows us to perform our advance design verification testing earlier in the development program, and with more meaningful results than is possible with other rapid prototyping approaches."

- Michael Friestad, Design Engineer – John Deere
Contemporary Cutting Processes

• Plasma Cutting

• Waterjet Cutting
Representative Parts of Many Materials
High-Speed Machining (HSM)

High Cutting Speeds and Feeds

Imply High Metal Removal Rates

(Typically 2 to 10 Times Higher)

Requires Structural and Process Dynamics Understanding

Applicable in Developed and Developing Countries
Design Issues Influencing Manufacturing Costs

• Standardization
• Reusable components
• Modular Architecture
• Electronics and Mechatronic Systems
• Regulatory Issues
• Design Optimization
Modular Architecture

- Backward/Forward Compatibility
- Plug and Play
- Open Architecture vs. Proprietary Architecture
- Increased Product Life
Electronics and Controls

- Increased electronic content as part of vehicle modularity and meeting technology requirements.
- Driven by modularity
- Issues:
  - Technology obsolescence
  - Supportability
Electronics Rapid Prototyping and Hardware-in-the-Loop

- **Rapid Control Prototyping**
  - Applying embedded code to a processor attached to the real world system.

- **Hardware-in-the-loop**
  - Code on actual processor applied to computer simulated system.
Mechatronics is a blending of mechanical, electrical, sensors and control systems to design intelligent systems, enabling x-by-wire applications that enhance the value and performance of off-road products:

- Fixed systems will be adjustable
- Manual adjustments will be powered
- Powered adjustments will be automatic
Regulatory Issues

- Emissions Requirements to meet TIER guidelines
- Safety and Automation
Optimization for Manufacturing, Assembly, and Service

• Developed industries are continuously challenged by ways to become more efficient
  – Design for Assembly
    • Evaluating product designs in a quantifiable way to identify unnecessary parts in an assembly and to determine assembly times and costs
  – Design for Manufacturing
    • Guidance in the selection of materials and processes and generates piece part and tooling cost estimates at any stage of product design
  – Design for Service
    • Assists manufacturers in meeting the demand for ease of serviceability.
Realization of high quality solutions through the effective integration of organized sets of components
Virtual Prototyping

• Integration of design and simulation in a Virtual Environment

Vehicle Model Design

\[ \alpha_f = \text{slip angle of front wheels} \]
\[ \alpha_r = \text{slip angle of rear wheels} \]
\[ a_x = \text{distance from center of gravity to front axle} \]
\[ a_y = \text{distance from center of gravity to rear axle} \]
\[ \beta = \text{slip angle of the center of gravity} \]
\[ F_f = \text{cornering force on the front wheels} \]
\[ F_r = \text{cornering force on the rear wheels} \]
\[ \delta = \text{steering angle} \]
\[ V = \text{vehicle speed} \]
\[ I_z = \text{mass moment of inertia about the center of gravity z axis} \]
\[ \dot{r} = \text{angular velocity about the CG} \]
\[ \theta = \text{angle of orientation} \]
\[ m = \text{mass of the vehicle} \]
\[ x = \text{vehicle CG's global x axis position} \]
\[ y = \text{vehicle CG's global y axis position} \]

Operator Model Design Iterations - Model Direction

- Operator Model
- Steering Rule Base
- FRCS Method
- Vehicle Control Unit
- Embedded Vehicle/Plant

Vehicle Maximum Turn Rate

Steer Rate of Correction

Operator Model Controller, Velocity = 1.5, Maximum Error = 0.14

Steering Rule Base Error

Global Coordinate Positions/Locations/Velocities
Accelerated Design Verification

Validate predictions of structural durability as calculated from computer generated "virtual" designs. A transitional is conducting full lifetime durability testing of vehicles or components as a cost effective and accelerated alternate to field evaluations.

Virtual Proving Ground Simulation and National Advanced Driving Simulator (NADS)

The National Advanced Driving Simulator allows off road equipment to be operated in realistic virtual environments while providing the human test operator sufficient realism to support engineering decision making before hardware is built.

NADS Motion base simulator

Operator View in NADS

Computer generated scene
Conclusions

• Additional efficiencies and quality of manufacturing will be built on the replacement of engineering manpower with accelerated design tools that:
  – Increase the quality of product by accurate modeling and analysis in the design process.
  – Reducing product cycle time
  – Providing more manufacturing flexibility to latent variables that change the manufacturing landscape.
America has been losing manufacturing jobs to China, Latin America and the rest of the developing world. Right?

Well, not quite.

It turns out that manufacturing jobs have been disappearing all over the world. Economists at Alliance Capital Management in New York took a close look at employment trends in 20 large economies recently, and found that since 1995 more than 22 million factory jobs have disappeared.

In fact, the United States has not even been the biggest loser. Between 1995 and 2002, we lost about 11 percent of our manufacturing jobs. But over the same period, the Japanese lost 16 percent of theirs. And get this: Many developing nations are losing factory jobs. During those same years, Brazil suffered a 20 percent decline.

Here's the real surprise. China saw a 15 percent drop. China, which is fast becoming the manufacturing capital of the world, has been losing millions of factory jobs.
What is happening to Manufacturing Jobs?

What's going on?

In two words: Higher productivity.

All over the world, factories are becoming more efficient. They've installed new equipment and utilized new technology. And that often means fewer jobs.

Market reforms have also played a role. In China, new modern factories are replacing large, inefficient state-run plants. The result is that even as China produces more goods than ever before, millions of factory workers have been laid off.

Manufacturing is following the same path as agriculture. As productivity rises, employment falls because fewer people are needed.

In 1910, almost a third of adult Americans worked on farms. Now, fewer than 3 percent do. But American agriculture is the most productive in the world.

Similarly, global manufacturing output is rising—since the mid-'90s, up 30 percent—even as worldwide manufacturing employment has been dropping. The two trends are directly related.

So next time you hear a politician complain that American manufacturing jobs are fleeing to low-cost countries like China or to Latin America, watch your wallet. Everyone's losing factory jobs.

• Robert Reich – Nov. 5, 2003 – Marketplace on NPR
“As tractors and combines amplify farmers, computer design workstations amplify engineers…”
“…In the 1970’s such an investigation on drafting boards might have engaged junior engineers for weeks…
“…Linked directly to manufacturing machines in the factory, design systems are on the verge of allowing a handful of engineers to make a cornucopia of excellent products, much as a few farmers in the air-conditioned cabs of powerful combines can harvest enough wheat to feed a city.”

(on the subject of the coming of the age of robots.)
A possible future?